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Impact of Eco-Enzyme Application on Nutrient Intake, Fiber Composition, and Feed Digestibility in PE Goats Using Agro-Industrial Waste-Based Complementary Feed

Andi Muh. Akram Dzulqaidah[1,*], Rohmiyatul Islamiyati[2] ,Marhamah Nadir[2] and Siti Yasya Ey Fathanah[3]

[1]Post graduate student, Faculty of Animal Science, Hasanuddin University, Makassar, South Sulawesi, Indonesia;[2]Animal Nutrition Department, Faculty of Animal Science, Hasanuddin University, Makassar, South Sulawesi, Indonesia;[3]Institute Technology and Health Permata Science Maros, South Sulawesi, Indonesia
[*]Corresponding author's e-mail: aaqramdzulqaidah22@gmail.com

The production of forage has diminished during the dry season, prompting farmers to utilize agro-industrial waste to ensure a continuous supply of feed. One of the wastes that can be utilized for the provision of feed is agro-industrial waste. Feed ingredients derived from agro-industrial waste have the disadvantage that some feed ingredients from agro-industrial waste have low nutritional content. Efforts are made to increase the nutritional content of agro-industrial waste by making complete feed. Consequently, incorporating eco enzymes into the complete feed is anticipated to improve both the intake and digestibility of nutrients in goats. This study aims to determine the characteristics of pH by putting 100 ml of eco-enzyme in a beaker then inserting the tip of the pH meter sensor, the tool will bring up the pH value of the liquid being measured and the cellulase enzyme activity using the DNS method on eco-enzyme from fruit peel waste applied to complete feed and the effect of eco-enzyme on complete feed from agro-industrial waste on consumption and digestibility of dry matter and organic matter. This study used Latin Square Design (LSD) with 4 treatments consisting of A = Complete feed without eco-enzyme, B = Complete feed + 0.5% eco-enzyme, C = Complete feed + 1% eco-enzyme, D = Complete feed + 1.5% eco-enzyme with 4 periods. The eco-enzyme demonstrated a pH of 2.67, with cellulase enzyme activity measured at 0.5526 U/mL and a total lactic acid bacteria (LAB) count of 2.2 x 10^6 CFU/mL. The results of this study indicate that the provision of eco-enzyme in agro-industrial waste feed can increase nutrient consumption and feed fibre fraction. In line with that, the provision of eco-enzyme in agro-industrial waste feed can increased digestibility with an eco-enzyme level of 1.5%. Therefore, it can be inferred that increasing the level of eco-enzyme in complete feed results in enhanced nutrient consumption and improved digestibility of both dry matter and organic matter.

Keywords: Eco-enzyme, PE goat, agro-industrial waste, complete feed, fruit peel waste.

INTRODUCTION

The Peranakan Etawa (PE) goat is a prominent local breed extensively raised in Indonesia, recognized for its superior qualities in both meat and milk production, adaptability to various environments, resistance to diseases, and unique physical characteristics. Research indicates that these goats achieve an average daily weight gain ranging from 59 to 67 grams (Zurahmah, 2019) and produce between 0.9 to 1.4 liters of milk per day (Astuti et al., 2017). This dual-purpose capability makes them valuable for both meat and milk production. To enhance the productivity of PE goats, it is essential to provide feed with high nutritional value. One of the potential alternative feed sources is the use of agro-industrial waste. The utilization of agro-industrial waste as animal feed will have two main impacts, namely Increased availability of animal feed materials especially In the dry season and reduce environmental pollution due to improper disposal of agro-industrial waste (Dilaga et al., 2023).

The majority of agro-industrial waste is characterized by low protein content, poor digestibility, and limited palatability, along with its substantial volume, which poses challenges in handling during transportation and storage. Consequently, there is a need to develop methods to augment the value of

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agro-industrial waste for use as animal feed (Utari et al., 2012). Utilizing these wastes not only reduces the costs associated with feed but also addresses environmental issues by minimizing the quantity of waste that must be managed (Sadh et al., 2018). Agricultural by-products often contain high levels of crude fibre and exhibit low palatability, which restricts their application as feed for ruminants (Santoso & Hariadi, 2009). Employing processing technologies such as fermentation and drying can significantly enhance the nutritional quality and digestibility of these wastes, making them a more effective feed option (Adewumi et al., 2011; Ebrahimi et al., 2018). Furthermore, perishable agro-industrial wastes can serve as components in complete feed mixtures.

Complete feed is a comprehensive dietary formulation that encompasses all essential nutrients necessary for animal health. This type of feed is specifically designed to fulfill the nutritional requirements of animals in a balanced way, promoting optimal growth and health without the necessity for supplementary feeding. Research conducted by (Marhamah et al., 2019) supports the notion that complete feed offers several advantages, including a more thorough nutritional profile and a taste that is favored by livestock, thereby enhancing the overall nutritional quality of animal feed.

The innovative process of transforming fruit peels into eco-enzyme via anaerobic fermentation offers substantial benefits. Eco-enzyme is composed of a variety of functional enzymes, such as amylase, lipase, caseinase, protease, and cellulase, in addition to secondary metabolites like flavonoids, quinones, saponins, alkaloids, and cardio glycosides (Vama & Cherekar, 2020). The activity of cellulase enzymes generated by microorganisms in eco-enzyme facilitates the breakdown of cellulose bonds. (Hernawati et al., 2010), noted that the reduction in crude fibre in fermented feed is affected by the density of cellulolytic bacteria, which is dependent on the nutrient sources available, thereby minimizing competition among microbes and promoting optimal growth and cellulose degradation. Additionally, Ginting (2023) revealed that the inclusion of cassava peel eco-enzyme in fermented animal feed significantly enhanced crude protein levels compared to treatments without fermentation. The objective of this research was to assess the effects of eco-enzyme in complete feed for PE goats, particularly regarding nutrient consumption, fibre composition, and digestibility.

The fermentation of complete rations based on agro-industrial waste with various inoculants leads to notable changes in nutrient content, which significantly impacts the in-vitro digestibility of dry matter and organic matter in PE goats (Dilaga et al., 2023). Moreover, the use of 100% silage from organic waste-based complete rations in ruminants has been shown to pose no risks of digestive disorders or metabolic issues (Lendrawati et al., 2012).

MATERIALS AND METHODS

The research materials were fruit peel waste eco-enzyme (banana, orange, pineapple, papaya, and dragon fruit) and agro-industrial waste complete feed (corn cob, ground corn, fine bran, coconut meal, shrimp head meal, molasses and mineral water mix).

Four Pernakan Etawa goats (12 months old) and 4 units of metabolic cages equipped with feeding and drinking places. This study used a 4 x 4 Latin Square Design (LSD) consisting of 4 treatments and 4 periods. The treatment arrangement was as follows:

A = Complete feed without eco-enzyme administration
B = Complete feed + added 0.5% eco-enzyme
C = Complete feed + 1% eco-enzyme added
D = Complete feed + 1.5% eco-enzyme added

Table 1. Replication design of treatments.

Periods	Treatment			
1	A	B	C	D
2	D	C	B	A
3	B	A	D	C
4	C	D	A	B

The preparation of rations for goats can be seen in Table 2.

Table 2. Preparation of rations for goat livestock (%)

Material	%	Crude protein	TDN	Ca	P
Corn cob	30	0.84	15.92	0.036	0.012
Ground corn	10	0.85	8.19	0.002	0.017
Rice bran	34	3.38	32.16	2.397	0.517
Coconut cake	10	1.86	5.55	0.090	0.107
Shrimp head flour	10	4.53	7.34	0.010	0.080
Molasses	5	0.21	4.05	0.042	0.048
Mineral vitamin mix	1	-	-	-	-
Amount	100	11.67	73.22	2.577	0.7808

Source: Result Data Calculation, 2024

The feed administered in this study was agro-industrial waste complete feed, with the nutrient content and fibre fraction provided in Tables 3 and 4.

Table 3. Nutrient content of agro-industrial waste in complete feeds (%)

Nutrient Content (%)	Treatments			
	A	B	C	D
Crude Protein	16.60	17.43	17.62	17.51
Extract Ether	4.43	4.42	4.56	4.45
Crude fibre	10.08	11.87	9.91	10.26
Nitrogen-free extract (NFE)	59.77	57.17	58.60	58.40
Organic Material (OM)	90.88	90.89	90.69	90.62

Source: Integrated Biotechnology Laboratory of Animal Science, Hasanuddin University 2024.
Description: A: No Treatment, B: 0.5% Eco-enzyme, C: 1% Eco-enzyme, D: 1.5% Eco-enzyme

This study used a metabolic cage measuring 120 cm long, 80 cm wide and 250 cm high. The type of goat used was PE goat with body weight ranging from 15 kg - 20 kg. Complete feed that has been mixed then given the addition of eco-enzyme according to the treatment of 0.5%, 1%, 1.5% and let stand for 24 hours then given 2 times a day in the morning (08:00) and evening (17:00) Central Indonesian Time for 4 periods (1 period = 14 days).

Table 4. Fibre fraction content of agro-industrial waste in complete feeds (%)

Content (%)	Treatment			
	A	B	C	D
NDF	30.42	28.86	29.10	27.63
ADF	14.11	14.48	13.72	13.71
Cellulose	10.60	10.34	10.12	10.73
Hemicellulose	16.31	14.38	15.38	13.92
Lignin	3.44	4.04	3.50	2.91
Insoluble ash	0.07	0.10	0.10	0.07

Source: Integrated Biotechnology Laboratory of Animal Science, Hasanuddin University 2024.
Description: A: No Treatment, B: 0.5% Eco-enzyme, C: 1% Eco-enzyme, D: 1.5% Eco-enzyme.

Measurement of feed consumption was carried out every day by weighing the amount of feed given minus the remaining feed. The amount of feed given was 3% of body weight. Feed collection was carried out for 5 days at the end of each period to measure the digestibility of Dry Matter (DM) and Organic Matter (OM) with the following formula:

$$\text{DM digestibility (\%)} = \frac{\text{Consuption DM} - \text{Feces DM}}{\text{DM Consuption}} \times 100\%$$

$$\text{OM digestibility (\%)} = \frac{\text{Consuption OM} - \text{Feces OM}}{\text{OM Consuption}} \times 100\%$$

***Statistical analysis*:** The data obtained were tabulated and calculated and then analysed using analysis of variance (ANOVA) according to the Latin Square Design (LSD) to determine the effect and continued with Duncan's further test to determine differences between treatments (Steel & Torrie, 1995).

RESULTS

The pH test results for eco-enzyme products yielded an average value of 2.67. A pH level below 4 signifies that the eco-enzyme product is in an acidic condition. According to Putra and Suyasa (2022) an optimal pH value during the fermentation of eco-enzyme is considered to be less than 4. Additionally, the analysis of cellulase enzyme activity in the eco-enzyme derived from fruit peel waste revealed an activity level of 0.5526 U/mL, while the total lactic acid bacteria (LAB) present in the fruit peel waste eco-enzyme was measured at 2.2 x 10^6 CFU/mL.
The results of feed consumption test and various ration formulas made from agro- industrial waste with the provision of eco-enzyme at various different levels showed no difference between treatments (P > 0.05). The average feed consumption results of PE goats are presented in Tables 5 and 6.

Table 5. Nutrient consumption (g/h/d).

Consumption	Treatment			
	A	B	C	D
Dry Matter (DM)	543.40	560.75	609.12	621.06
Organic Matter (OM)	493.20	508.81	552.73	563.70
Crude Protein	94.26	97.29	105.93	106.85
Extract Ether	24.25	24.97	27.33	27.73
Crude Fibre	57.71	59.18	63.29	64.51
NFE	316.95	327.35	356.15	364.65

Description: A: No treatment, B: Complete feed + 0.5% eco-enzyme, C: Complete feed + 1% eco- enzyme, D: Complete feed + 1.5% eco-enzyme

The results of the DM digestibility test made from agro-industrial waste with the provision of eco-enzyme at various levels showed no difference between treatments (P> 0.05). The average results of DM digestibility of PE goats are presented in Figure 1.

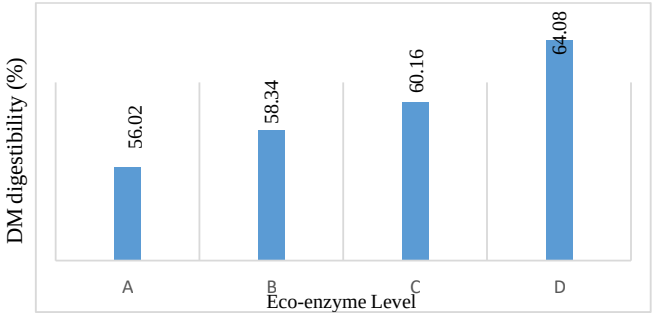

Figure 1. Dry matter digestibility.
Description: A: No treatment, B: Complete feed + 0.5% eco-enzyme, C: Complete feed + eco-enzyme 1%, D: Complete feed + 1.5% eco-enzyme

The results of the OM digestibility test made from agro-industrial waste with the provision of eco-enzyme at various levels showed no difference between treatments (P> 0.05). The average results of OM digestibility of PE goats are presented in Figure 2.

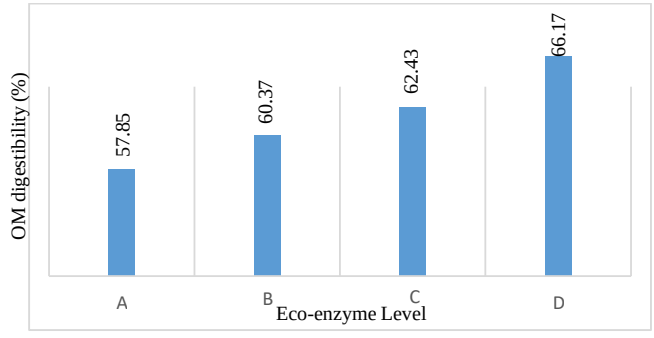

Figure 2. Organic matter digestibility.

Description: A: No treatment, B: Complete feed + 0.5% eco-enzyme, C: Complete feed + eco-enzyme 1%, D: Complete feed + 1.5% eco-enzyme

The data presented in Table 6 regarding the influence of eco-enzyme on the feed consumption of PE goats, utilizing complete feed derived from agro-industrial waste, indicated that there was no statistically significant effect (P>0.05) on the consumption of fibre fractions. However, it was observed that the consumption by the goats increased in correlation with the rising levels of eco-enzyme.

Table 6. Fiber fraction consumption of goats (g/h/d).

Consumption	Treatment			
	A	B	C	D
NDF	156.70	160.33	176.25	181.28
ADF	76.13	78.27	84.82	86.86
Cellulose	56.80	59.10	63.24	64.99
Hemicellulose	80.57	82.07	91.43	94.44
Lignin	18.88	18.74	21.06	21.36
Insoluble ash	0.46	0.45	0.53	0.51

Description: A: No treatment, B: Complete feed + 0.5% eco-enzyme, C: Complete feed + 1% eco- enzyme, D: Complete feed + 1.5% eco-enzyme.

DISCUSSION

This research investigates the application of eco-enzyme and complete feed derived from agro-industrial waste, aiming to enhance nutrient intake, fiber composition, and the digestibility of dry matter (DM) and organic matter (OM) in goats. Agro-industrial by-products, such as corn cobs, are generated during the processing of agricultural and food products and are frequently regarded as waste. However, these by-products possess significant potential as alternative animal feed sources. Agro-industrial wastes are rich in protein, fiber, and minerals, which can fulfill the nutritional requirements of livestock, particularly goats, thereby promoting increased meat production (Akinfemi et al., 2012). The provision of eco-enzyme in agro-industrial waste complete feed showed no significant effect on dry matter consumption. The consumption of dry matter is affected by the rumen's capacity to absorb it, as well as the rapid passage of feed material from the rumen, which indicates the quantity of feed ingested (Astuti et al., 2015). The diminished dry matter intake noted in the control treatment is thought to stem from the limited capacity of the livestock to ingest the available feed. The data on the average organic matter consumption in goats, as illustrated in Table 5, indicates a direct correlation with dry matter consumption. This suggests a significant relationship between the two variables, as organic matter constitutes a component of dry matter. Furthermore, the elevated levels of organic matter presented in Table 3 reinforce this connection. This aligns with the findings of Libra et al. (2014), which indicate that the level of dry matter intake influences the intake of organic matter; as the consumption of dry matter rises, so does the consumption of organic matter, and vice versa.

Crude protein constitutes a significant organic component within the dietary ration, and its intake is primarily influenced by the consumption of dry matter and the concentration of crude protein present in the ration (Ratu et al., 2020). In this investigation, the highest crude protein intake was observed in treatment D, which recorded an average of 106.95 grams per head per day. The elevated crude protein consumption associated with the treatment incorporating eco-enzyme can be attributed to the substantial crude protein nutrient content detailed in Table 3. Furthermore, the findings of this study surpass those reported by Henuk et al. (2020), who documented an average crude protein consumption of 57.56 grams per head per day when utilizing silage made from kume grass and forest passion fruit leaves in varying proportions. The findings of this research indicate that the results surpass those reported in the study by Ratu et al. (2020), which utilized red lemongrass flour as a natural antibiotic crude protein consumption, yielding an average of 24.43 grams per head per day. Notably, the crude fat content in treatment D was higher than that observed in feed treatments A and B. Elevated fat levels in feed ingredients, as shown in Table 3, can impede the activity of rumen microbes, particularly in the digestion of crude fibre. An excess of fat in the rumen can coat the fibre's surface, thereby hindering microbial digestion of the feed material (Soder et al., 2011). Treatment D exhibited the highest levels of crude fat, crude fibre, and nitrogen-free extract (NFE) consumption compared to the other treatments. This can be attributed to the high palatability of the eco-enzyme present in treatment D, which encouraged livestock to consume more feed than those receiving alternative treatments. The appealing aroma of the eco-enzyme in treatment D is a significant factor in attracting livestock to consume the agro-industrial waste-based complete feed.

The elevated digestibility value observed in the eco-enzyme treatment (Figure 1) can be attributed to the presence of lactic acid bacteria (LAB), cellulolytic bacteria, and amylolytic bacteria. These microorganisms not only facilitate a reduction in pH through the production of organic acids from LAB but also contribute to the degradation of fibre content via cellulolytic bacteria (Wulandari et al., 2014). Furthermore, the enhancement in digestibility is likely influenced by the incorporation of additional soluble carbohydrates, which serve as a substrate for rumen microorganisms during their initial growth phases. The availability of adequate energy sources throughout the fermentation process supports microbial activity, thereby improving their efficiency in breaking down the crude fibre present in the substrate. The lower the crude fibre, the higher the digestibility of the ration because it is influenced by several factors including the level of crude fibre in the feed, the composition of the crude fibre

constituents and the activity of microorganisms (Kaleka et al., 2021). In addition to the content and amount of crude fibre (Table 3) in the ration, another factor that affects digestibility is the activity of cellulolytic bacteria in the rumen. This is supported by Maynard et al. (2005) which states that digestibility is strongly influenced by several factors including the level of fibre in the feed, the composition of crude fibre constituents and the activity of microorganisms. The results of this study are also in line with those reported by Nii and Okabe (2012) that the potential degradation of feed before and after fermentation has increased. Through the use of microbes in fermentation, the enzymes produced are able to release the bonds of simple compounds that allow an increase in the digestibility value of feed (Mahakka et al., 2014).

The provision of *eco-enzyme* in complete feed from agro-industrial waste showed no significant effect on fibre fraction consumption. The increase in fibre fraction consumption (Table 6) for livestock is in line with the increase in quality and digestibility of the feed given, while feed digestibility depends on the fibre content that cannot be utilized by livestock (Ali, 2006). Treatment D, which utilized an eco-enzyme concentration of 1.5%, exhibited the greatest consumption of fibre fractions, while the fibre fraction content was observed to decrease in comparison to the other treatments (Table 4). This phenomenon can be attributed to the relatively low crude fibre content of the 1.5% eco-enzyme, coupled with its high palatability, which encourages livestock to consume a greater quantity of feed in Treatment D than in the alternative treatments. The reduction in crude fibre content is attributed to the activity of the cellulase enzyme, measured at 0.5526 U/mL, produced by cellulolytic microorganisms present in the eco-enzyme. This decline in crude fibre is a result of the fermentation process of the eco-enzyme, which generates cellulase that facilitates the breakdown of crude fibre. This finding is consistent with the research conducted by Hernawati et al. (2010), which indicates that the reduction in fibre content in fermented feed is influenced by the population of cellulolytic bacteria. The availability of nutrient sources minimizes competition among microbes, allowing for optimal growth and enhancing the efficiency of cellulose degradation in feed materials.

***Conclusion*:** The eco-enzyme derived from fruit peel waste produced a pH value of 2.67, a cellulase enzyme activity measured at 0.5526 U/mL, and a total lactic acid bacteria (LAB) count of 2.2 x 10^6 CFU/mL. Higher levels of eco-enzyme in the complete feed increased nutrient consumption, fibre fraction and digestibility of dry matter and organic matter.

***CRediT author statement*:** Andi Muh. Akram Dzulqaidah, Acquisition of data, Rohmiyatul Islamiyati and Marhamah Nadir, conception and design of study, Andi Muh. Akram Dzulqaidah, Rohmiyatul Islamiyati, Marhamah Nadir, Siti Yasya Ey Fathanah drafting the manuscript.

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***Availability of data and material*:** All data is published in this manuscript.

***Consent for publication*:** All authors submitted consent to publish this research article in JGIAS.

***SDGs addressed*:** Zero Hunger; Responsible Consumption and Production; Climate Action.

***Informed consent*:** N/A

***Policy reffered*:** Sustainable agriculture, Food security, Agri-environmental policy.

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